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FINAL REPORT

GRANT AF-AFOSR 9-65

April 1, 1965 - March 31, 1966

Investigations in the Field of Relational Biology

During the period of the above-referenced grant, we continued our work on the properties of the class of metabolic models which we called (M, R)-systems. The work was facilitated in having available the services of Mr. John Bramsen and Mr. Lloyd A. Demetrius as research assistants, and Dr. B. L. Foster as research associate. Each of these individuals made a useful contribution to the work of the grant during the grant period.

Mr. Bramsen was concerned with investigating the relationship between the (M, R)-systems and the rather different relational biology developed by N. Rashevsky in a series of papers (cf. N. Rashevsky, "Topology and Life," Bulletin of Mathematical Biophysics, 16 (1954), 317-348). In this abstract biology, Rashevsky assumes that every relational biological structure has arisen in a canonical fashion from some primordial structure P, and that the canonical rules thus associate with each primordial P a class of possible "transformed" structures T(P). Bramsen found in the course of his investigation (Bramsen, 1966) that the primordial P is effectively determined by any sufficiently comprehensive subset of T(P), and found a set of conditions under which each structure in T(P) determines the primordial effectively and uniquely. The biological significance of this result is the following: if we suppose that the primordial corresponds to some eobiotic form which has long since disappeared from the planet, then we can always, from a sufficiently comprehensive set of extant biological organizations, determine effectively what the relational structure of the primordial must have been. If Bramsen's conditions on T are satisfied, then indeed any extant structure will uniquely and effectively determine the primordial. And once the primordial P is known, then the entire set T(P) of possible biological organizations is completely determined.

Mr. Demetrius has concerned himself with certain aspects of what we called in a previous report the Central Problem of the theory of (M, R)-systems; namely, the conditions under which an environmentally induced alteration of "metabolic" structure of these systems can be reversed by a further sequence of environmental alterations. In his recent note (Demetrius, 1966) he has applied his extensive background in the theory of automata to the study of important questions concerning the relation of the outputs of the altered [illegible] ing the analog o[illegible] t to have some [illegible]

Dr. Fos[illegible] the re-estab[illegible] his note (Fo[illegible] tence of a n[illegible] r hypothesis o[illegible] Dr. Foster is an [illegible] ng himself to th[illegible] control in dyna[illegible]

A number of other papers have been forthcoming during the grant period, in which a variety of results have been derived. The paper (Rosen, 1966a) takes up in detail the question of the induced replication maps, which we showed in earlier work (Rosen, Bulletin of Mathematical Biophysics, 21 (1959), 109-128) must exist when certain natural restrictions are placed on the system. This restriction can be interpreted to mean that any two possible "genetic" components which agree on any input must agree on every input. This type of conclusion shows again the power of relational arguments, in that a general assertion of this type could not be inferred from purely metric considerations. This conclusion, moreover, is highly reminiscent of the properties of trajectories of dynamical systems, which are either disjoint or identical. A rather deep analogy with dynamical systems is thus indicated and arises from different considerations than those we suggested in previous reports. As we have remarked in the previous paragraph, the elucidation of these analogies is presently under way.

A second paper (Rosen, 1966b) is concerned with the mathematical "naturality" of the concept of (M, R)-system, as opposed to its biological naturality. In particular, we show that the class of (M, R)-systems which can be constructed from the sets and mappings of a given category is itself a category. Quite recently, Michael Arbib, a mathematician and system theorist at Stanford, used this result to characterize the class of sequential machines which arise from (M, R)-systems, and using this characterization, he proved a somewhat stronger version of our theorem.

We are currently in the process of preparing the first paper of a series relating (M, R)-systems to dynamical systems, analogous to our papers relating (M, R)-systems to sequential machines. When this has been accomplished, we shall have at hand a formalism equipped to deal with all these areas in a unified manner, and thence to find the conditions under which the Central Problem can be solved affirmatively.

PAPERS ARISING FROM GRANT

1. Bramsen, John. 1966. "A Matrix Approach to the Theory of Biotopological Mapping." Bull. Math. Biophysics, 28, 107-11[illegible].

2. Demetrius, L. A. 1966. "Abstract Biological Systems as Sequential Machines: Behavioral Reversibility." Bull. Math. Biophysics, 28 (in press).

3. Foster, B. L. 1966. "Re-establishability in Abstract Biology." Bull. Math. Biophysics, 28 (in press).

4. Rosen, R. 1966a. "A Note on Replication in (M, R)-systems." Bull. Math. Biophysics, 28 (in press).

5. ________. 1966b. "Abstract Biological Systems as Sequential Machines III." Bull. Math. Biophysics, 28 (in press).

6. ________. "Abstract Biological Systems as Dynamical Systems." In preparation.

Robert Rosen
Principal Investigator

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13. ABSTRACT

A variety of results dealing with questions arising in the relational theory of biological systems are described. These results are concerned with replication of "genetic" components of (M, R)-systems, with the structure of the class of (M, R)-systems which can be formed from the objects and mappings of a given category, with aspects of re-establishability and environmental alterations in these systems, and with some interesting properties of a relational biology first described by N. Rashevsky.

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